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Ishimoto et al.

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(54) **DISPLAY DEVICE**

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(51) **Int. Cl.**
G09G 3/28 (2006.01)

(52) **U.S. Cl.** **345/60**; 345/63; 345/65; 345/66; 345/67; 345/69

(58) **Field of Classification Search** 345/60–69, 345/213, 691, 1.3; 313/484, 514, 582–585, 313/1, 3; 315/169.4, 169.1
See application file for complete search history.

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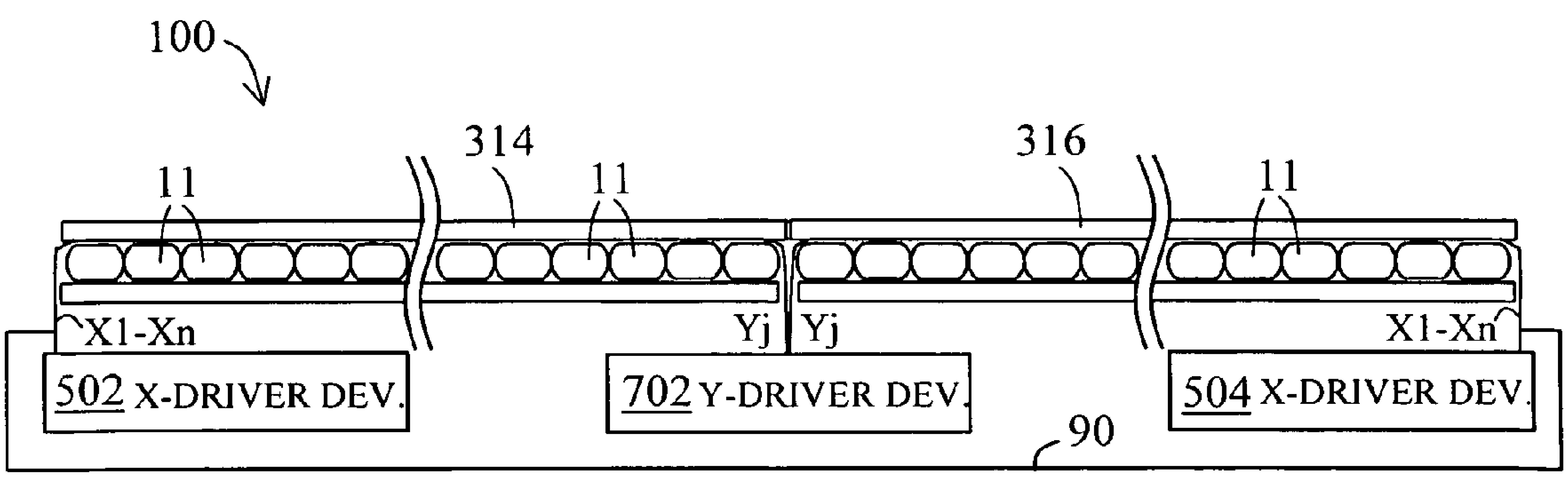
(74) *Attorney, Agent, or Firm* — Staas & Halsey LLP

(57) **ABSTRACT**

A display device includes two or more plasma tube array units to provide a large sized screen. Each plasma tube array unit includes pairs of scan and sustain electrodes. The plasma tube array units are disposed adjacent to each other in a longitudinal direction of the scan and sustain electrodes. One scan driver which selectively applies a scan signal to the scan electrodes is coupled to the two adjacent plasma tube array units at a position between the two adjacent plasma tube array units. Two sustain voltage drivers which apply respective sustain voltage to the sustain electrodes are coupled to the sustain electrodes of the two respective adjacent plasma tube array units on two respective outermost sides of the two respective adjacent plasma tube array units.

17 Claims, 7 Drawing Sheets



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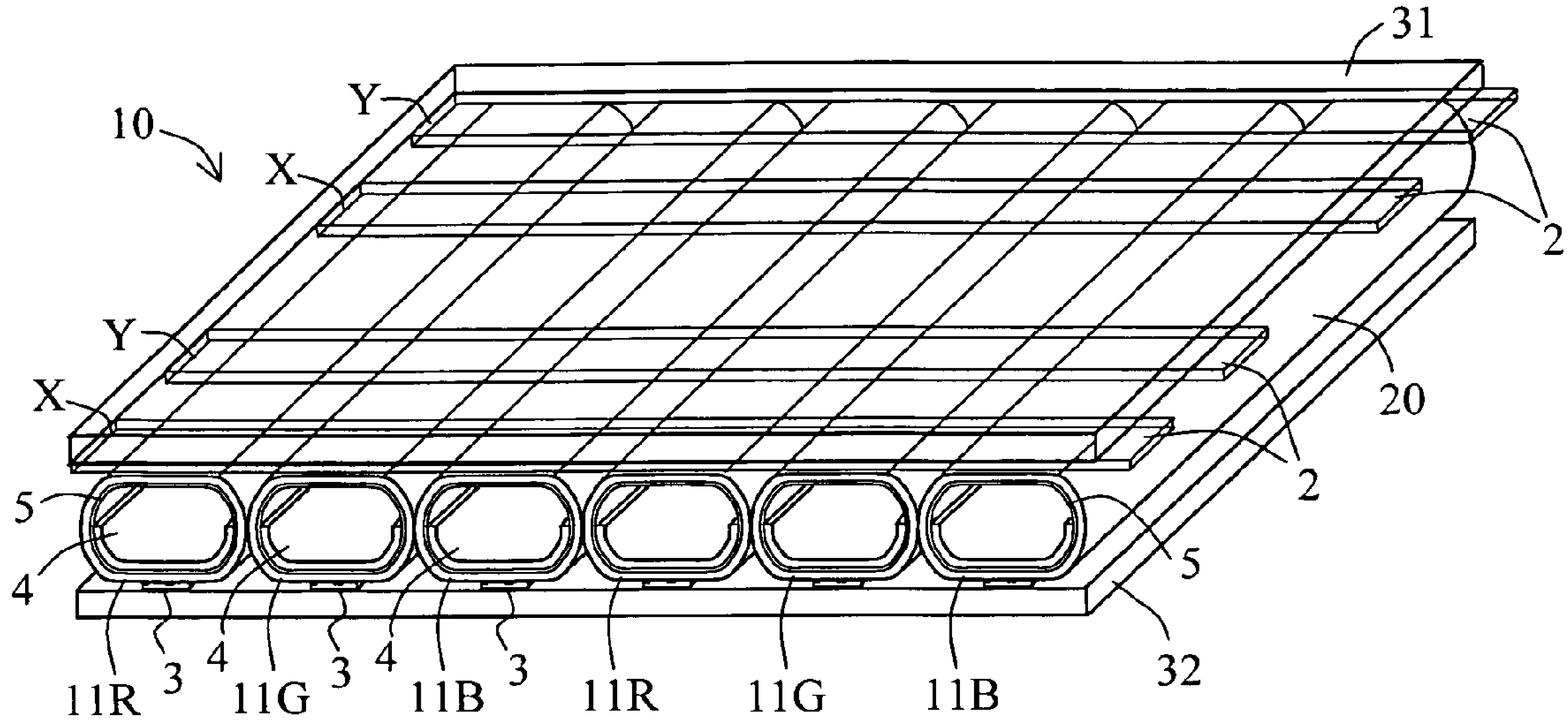


FIG. 1

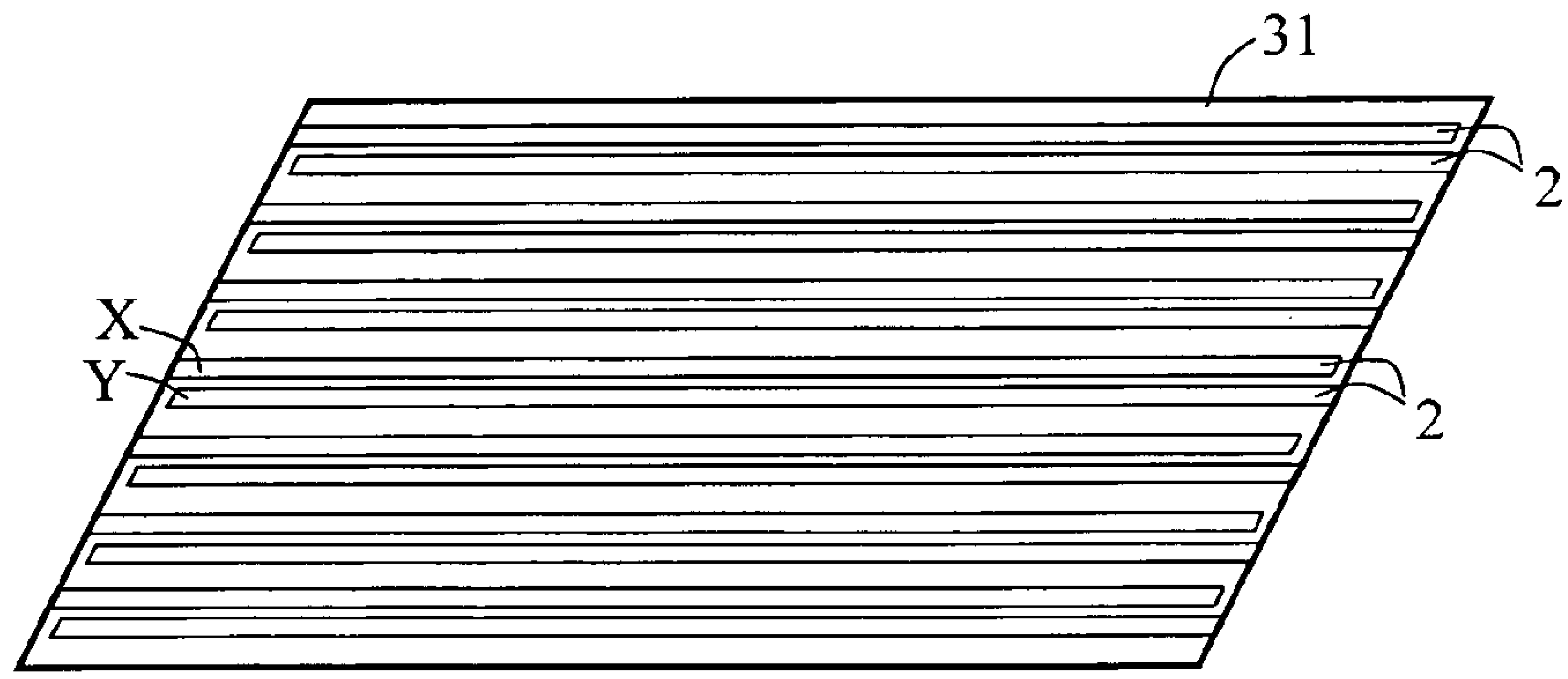


FIG. 2A

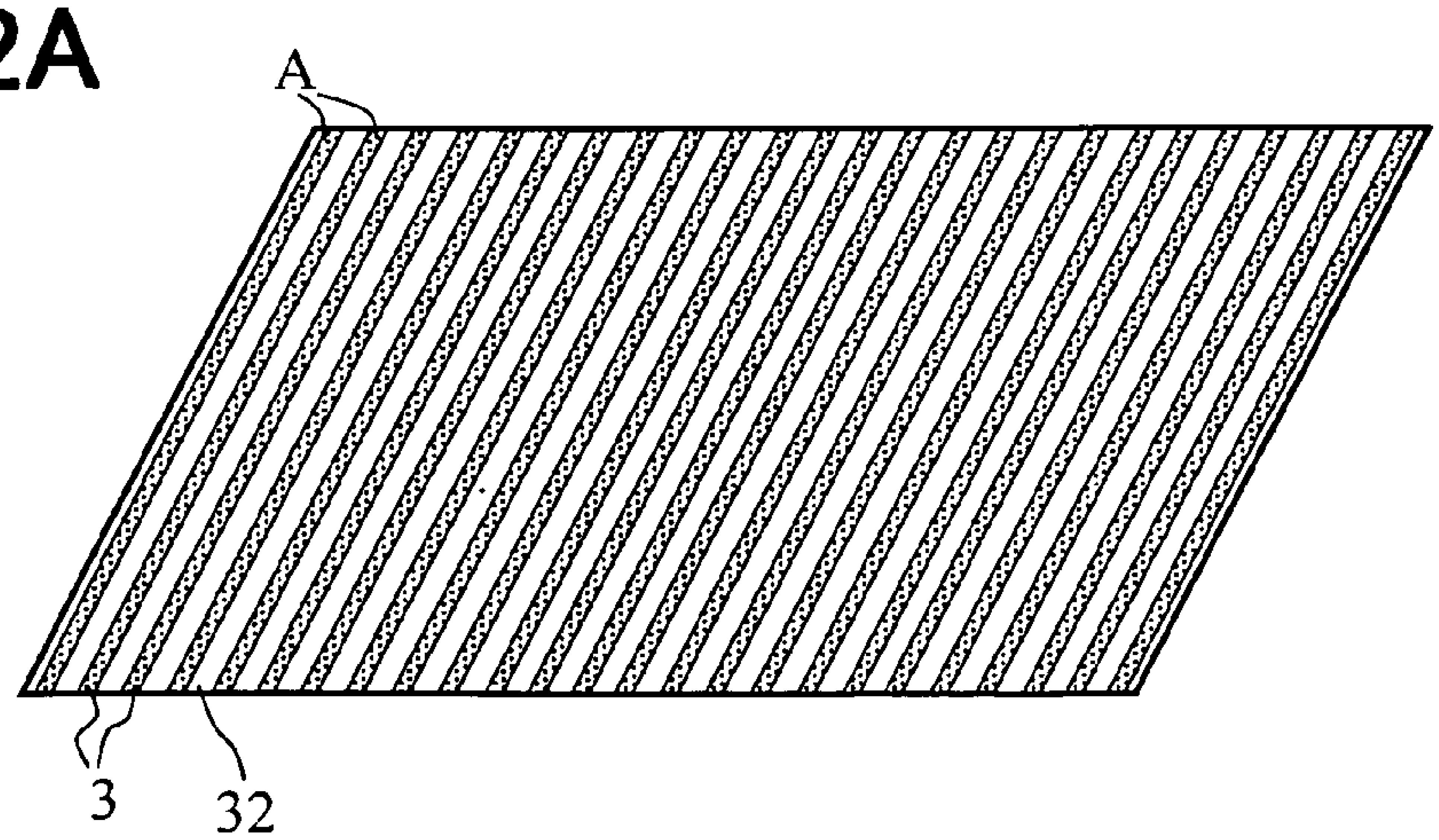


FIG. 2B

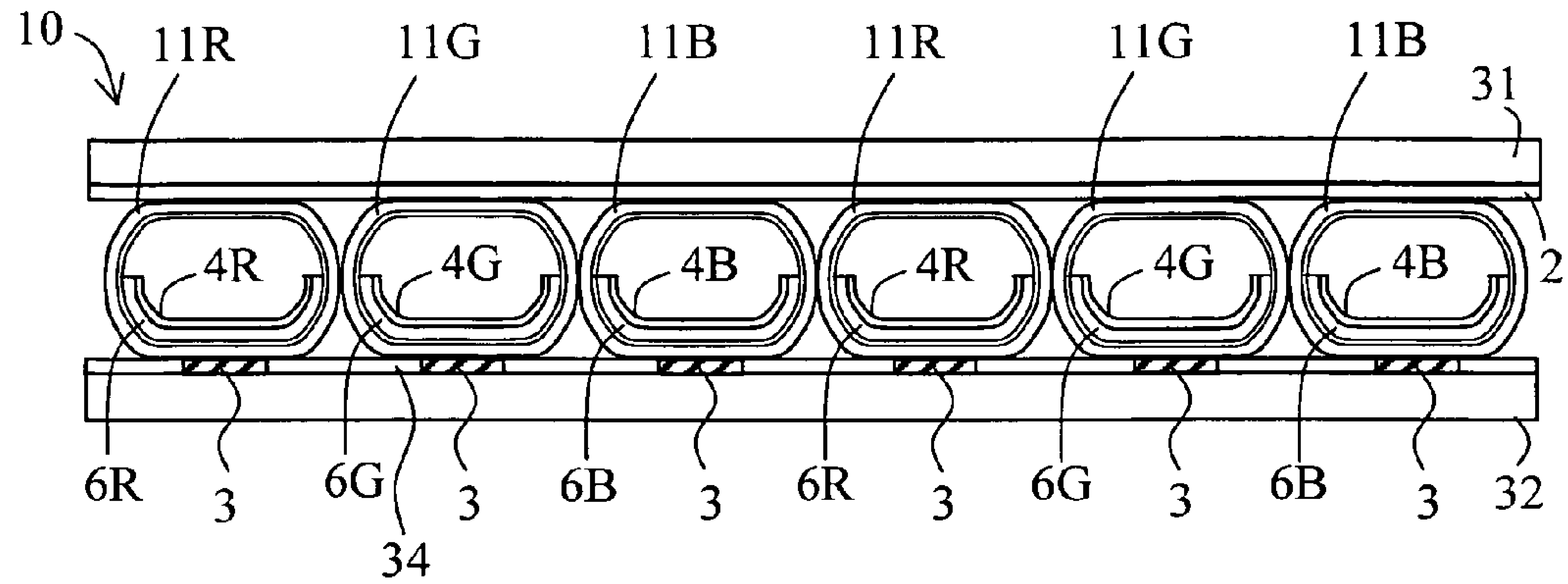
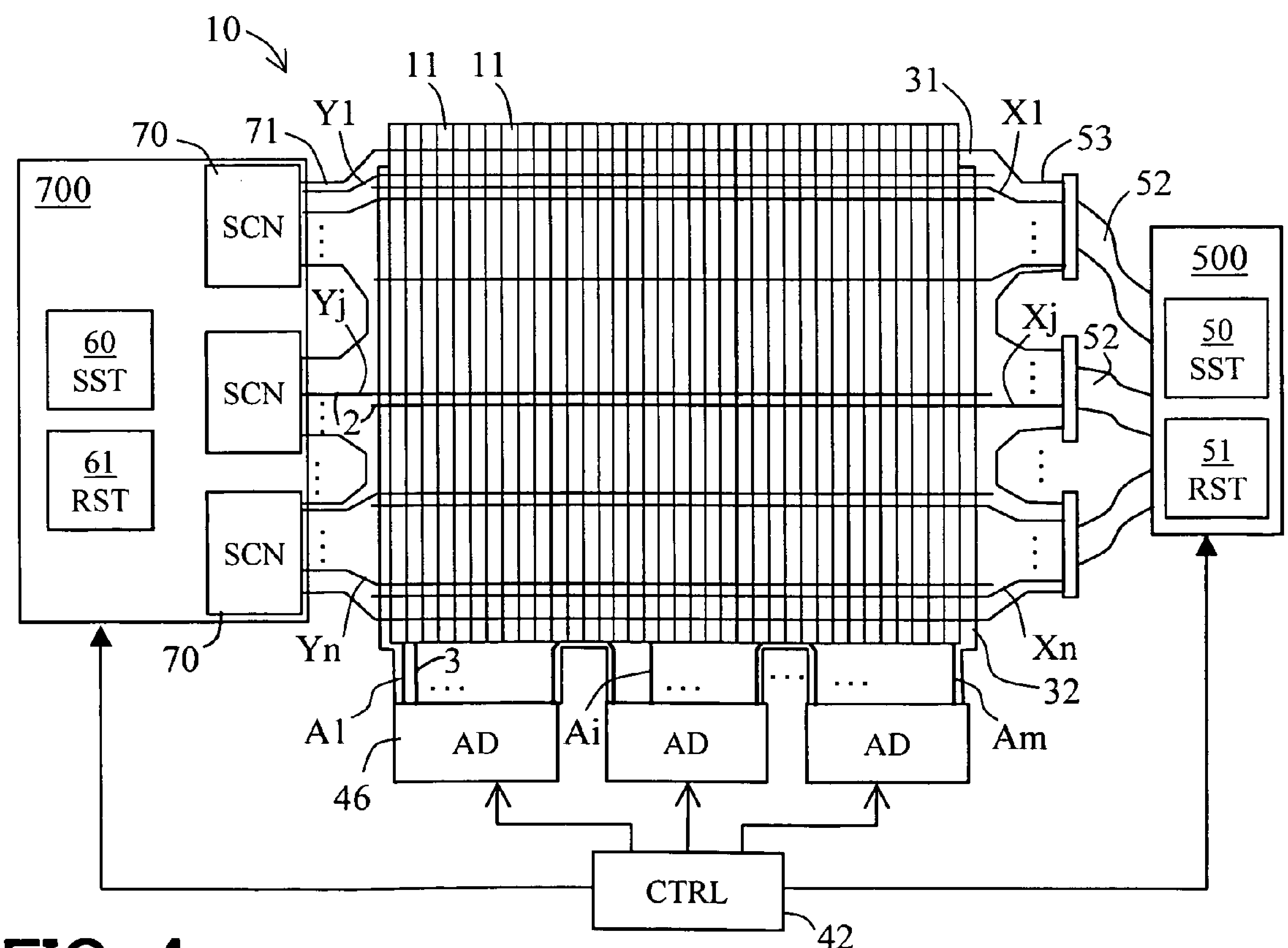

10
11R
11G
11B
11R
11G
11B
31
2
4R
4G
4B
4R
4G
4B
6R
3
6G
34
3
6B
3
6R
3
6G
3
6B
3
32

FIG. 3


10
11
11
31
70
71
Y1
X1
53
52
700
SCN
500
Yj
Xj
52
60
SST
50
SST
SCN
2
61
RST
51
RST
SCN
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Yn
Xn
3
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A1
Ai
Am
AD
AD
AD
46
CTRL
42

FIG. 4

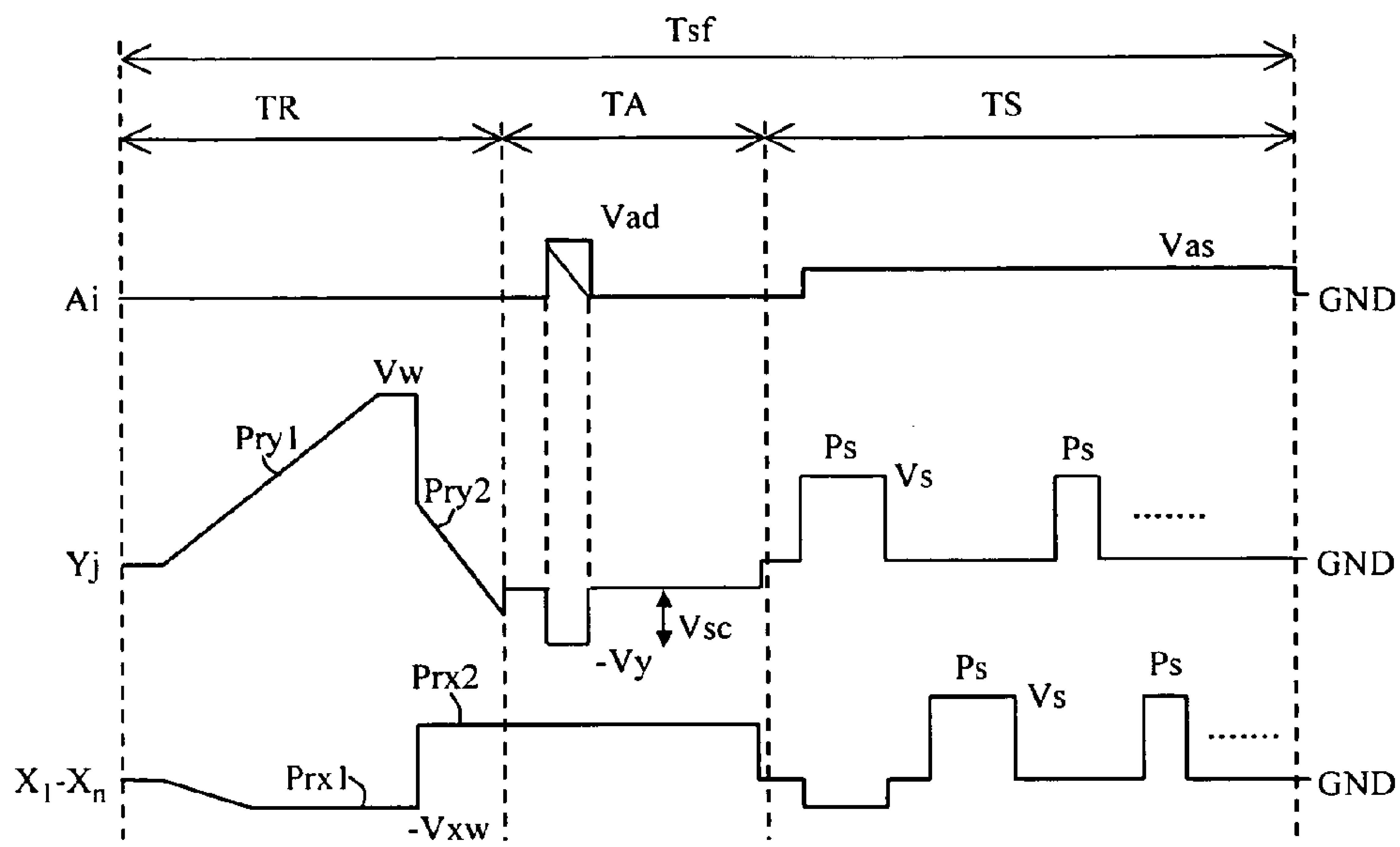
Tsf
TR
TA
TS
Vad
Vas
Ai
GND
Vw
Pry1
Pry2
Ps
Vs
Ps
Yj
GND
Vsc
-Vy
Prx2
Ps
Vs
Ps
X1-Xn
Prx1
-Vxw
GND

FIG. 5

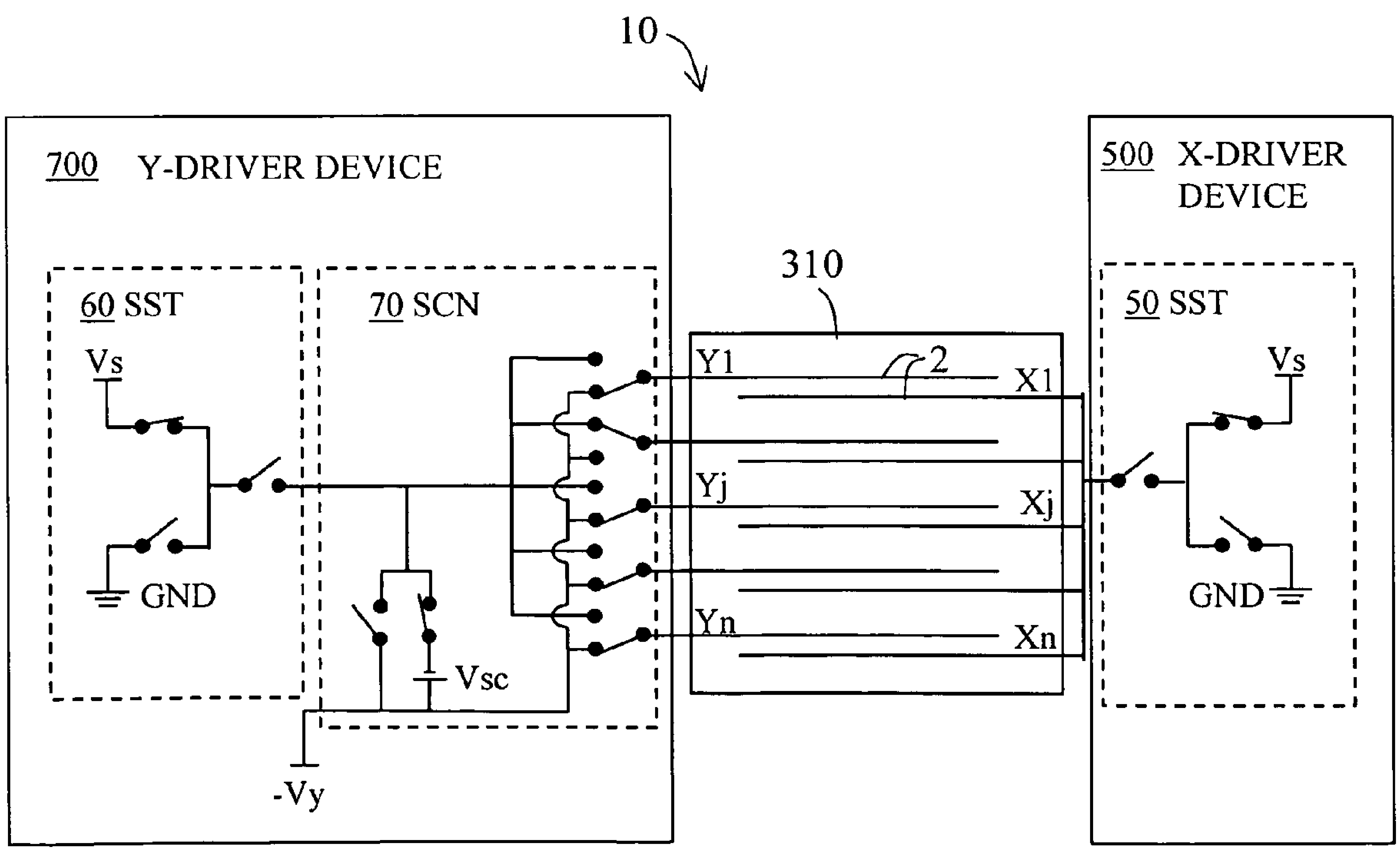
10
700 Y-DRIVER DEVICE
500 X-DRIVER DEVICE
310
60 SST
70 SCN
50 SST
Vs
GND
Vsc
-Vy
Y1
Yj
Yn
X1
Xj
Xn
2
Vs
GND

FIG. 6

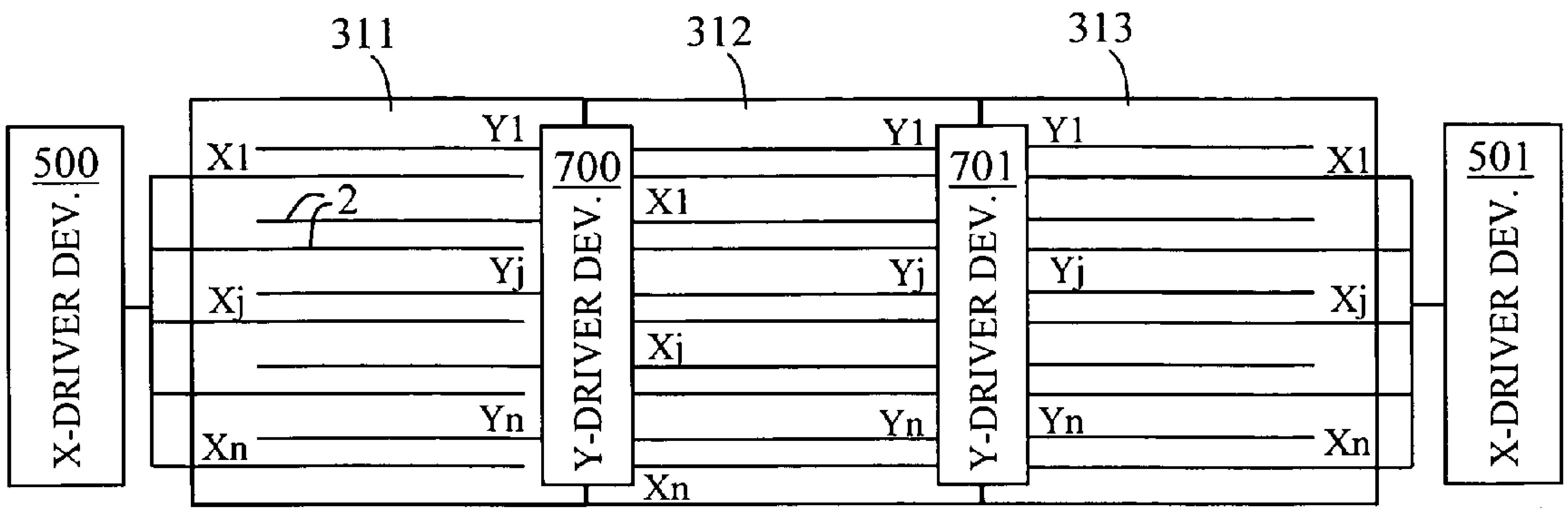
311
312
313
500
X-DRIVER DEV.
700
Y-DRIVER DEV.
701
Y-DRIVER DEV.
501
X-DRIVER DEV.
X1
Y1
2
Xj
Yj
Xn
Yn

FIG. 7A

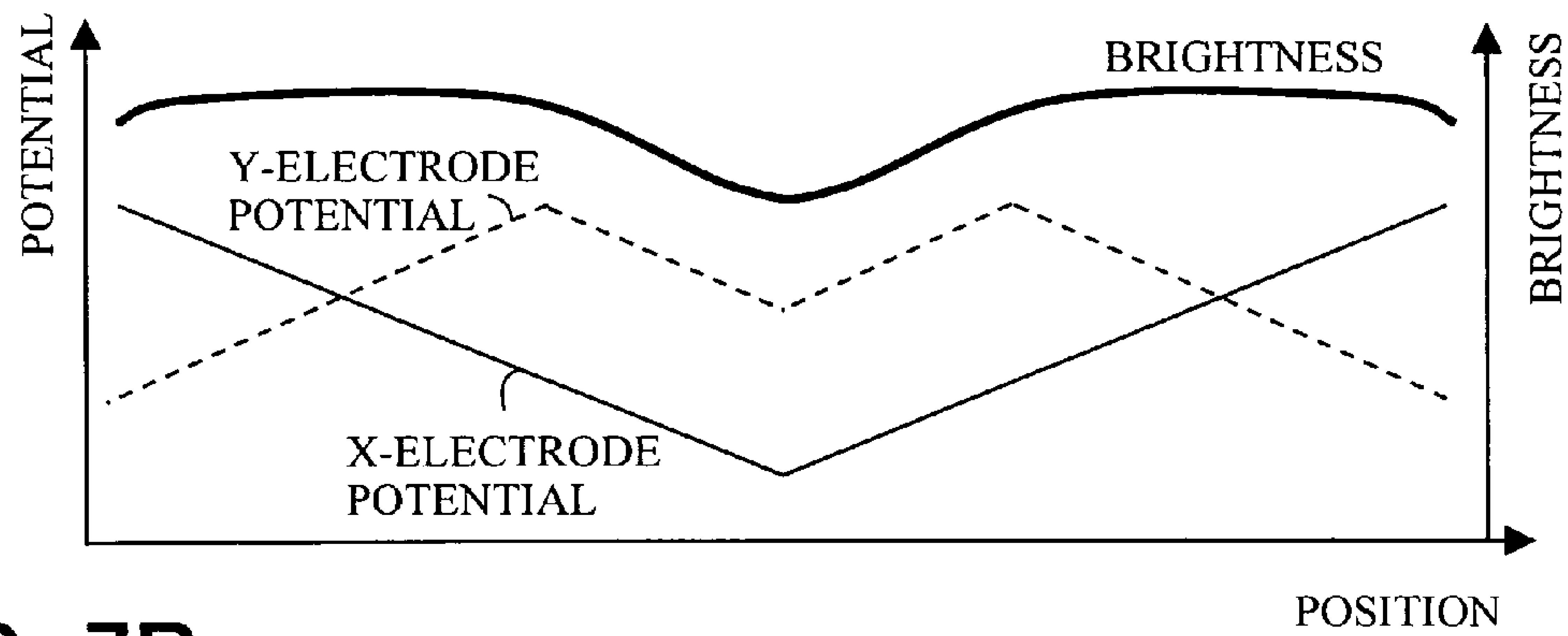
POTENTIAL
BRIGHTNESS
BRIGHTNESS
Y-ELECTRODE
POTENTIAL
X-ELECTRODE
POTENTIAL
POSITION

FIG. 7B

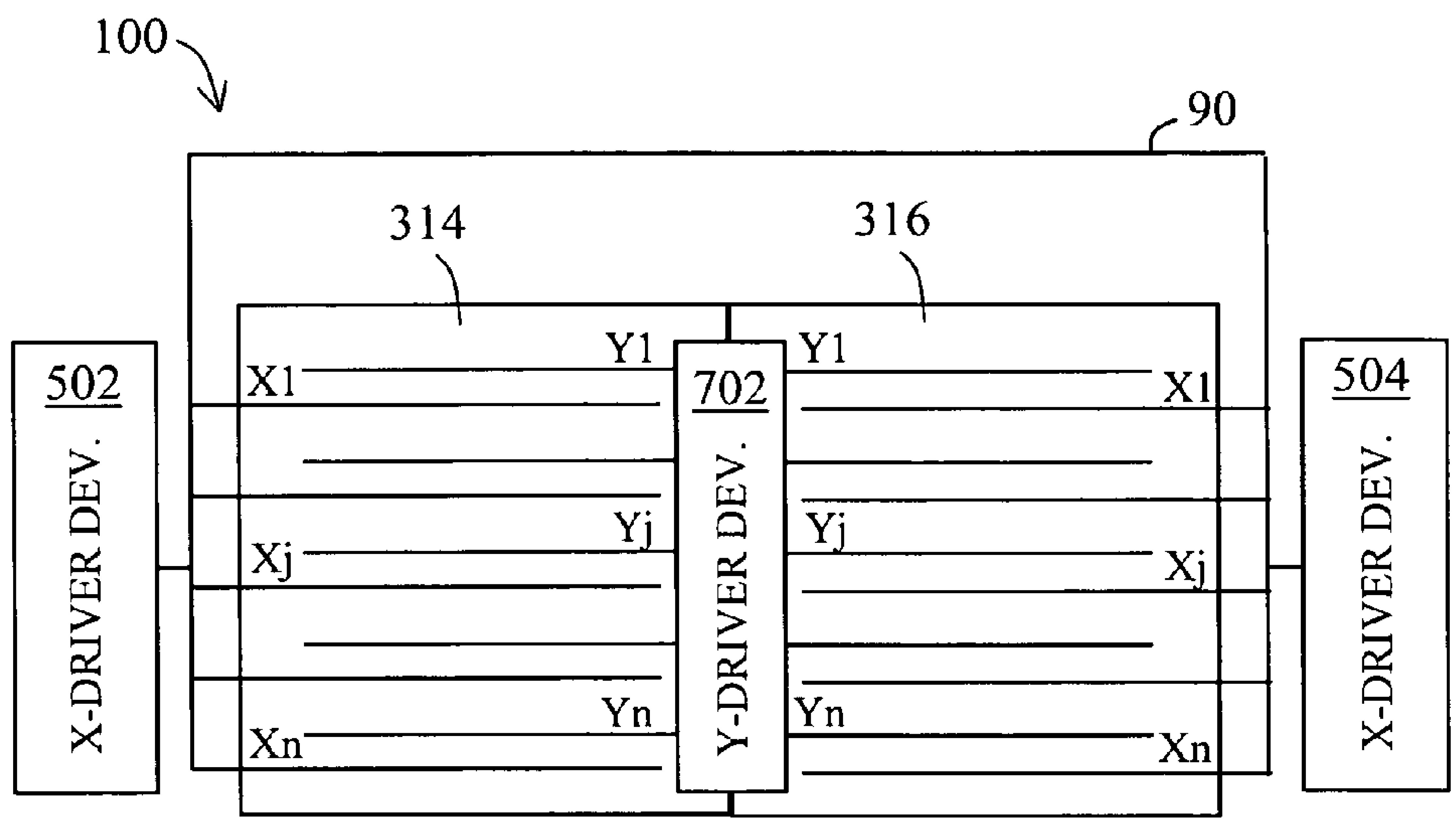

FIG. 8A

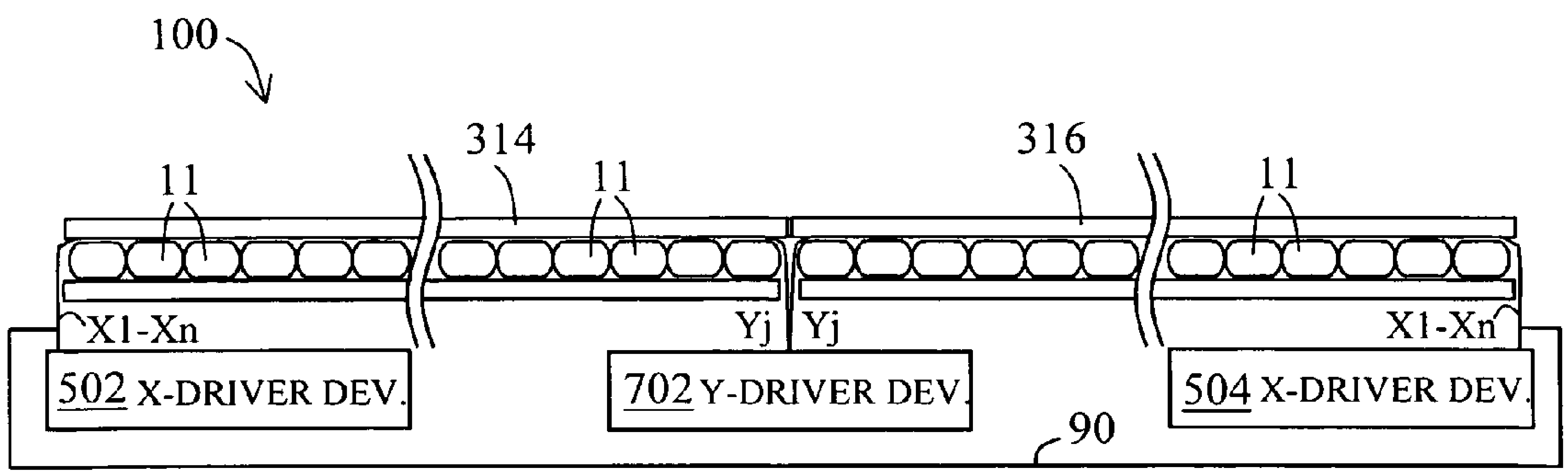

FIG. 8B

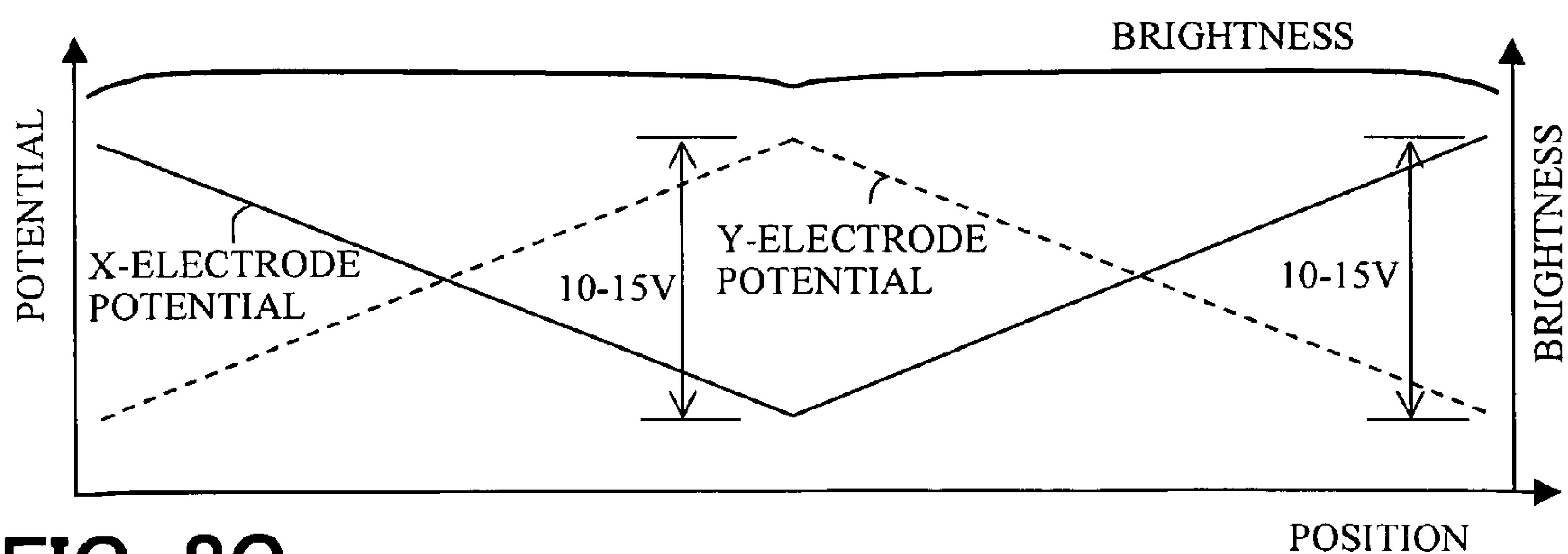

FIG. 8C

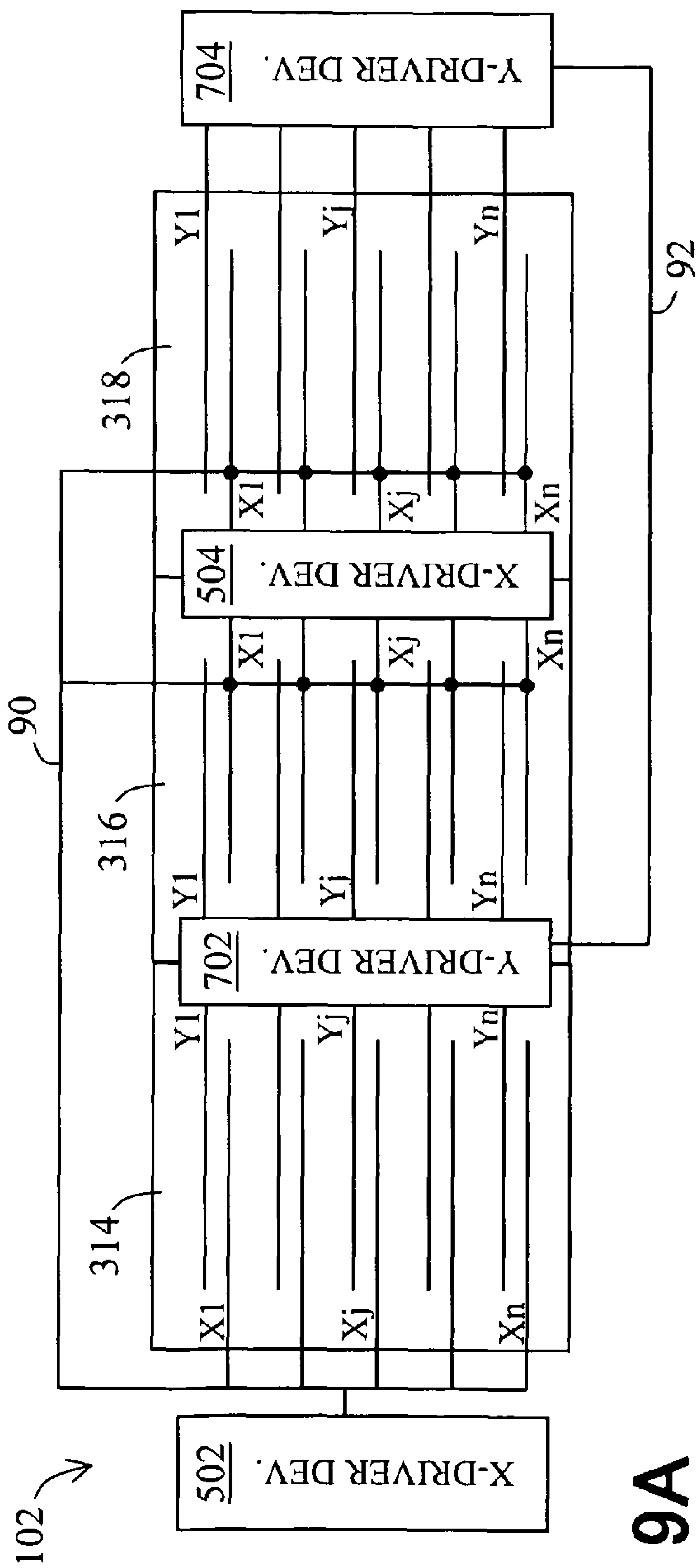
102
502 X-DRIVER DEV.
504 X-DRIVER DEV.
702 Y-DRIVER DEV.
704 Y-DRIVER DEV.
314
316
318
90
92
X1
Xj
Xn
Y1
Yj
Yn

FIG. 9A

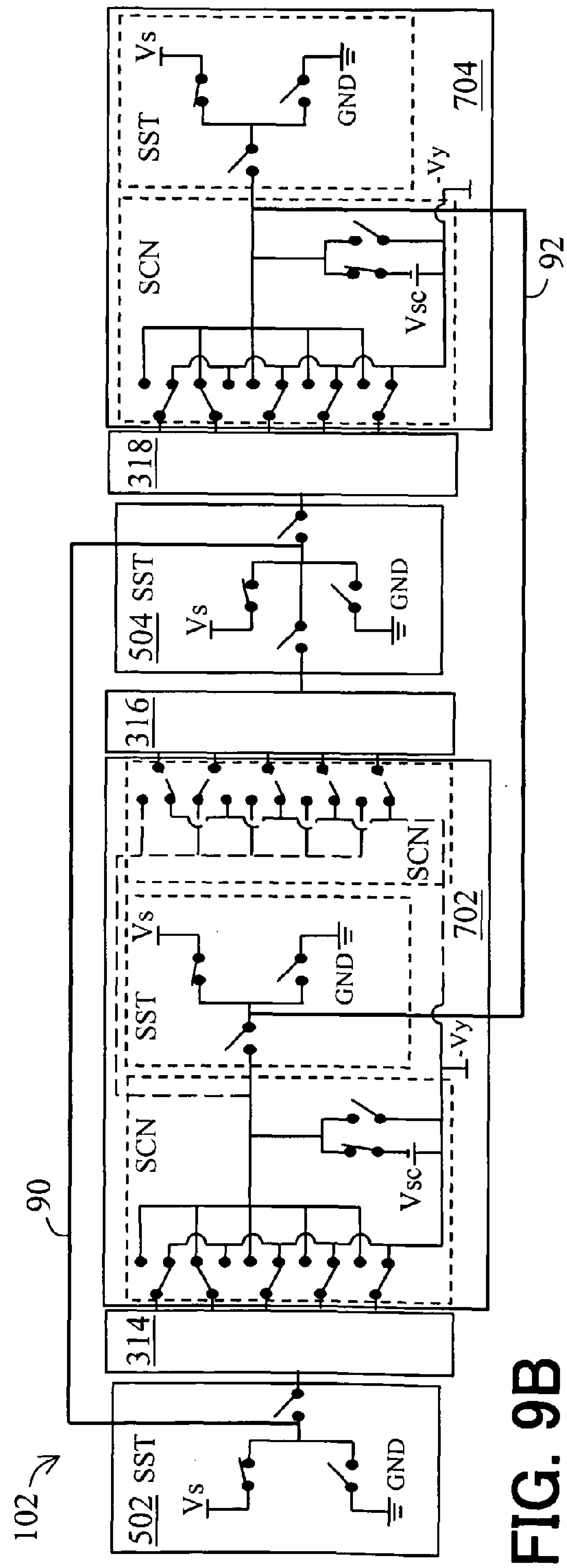
102
502 SST
504 SST
Vs
GND
314
316
318
702
704
SST
SCN
Vsc
-Vy
90
92

FIG. 9B

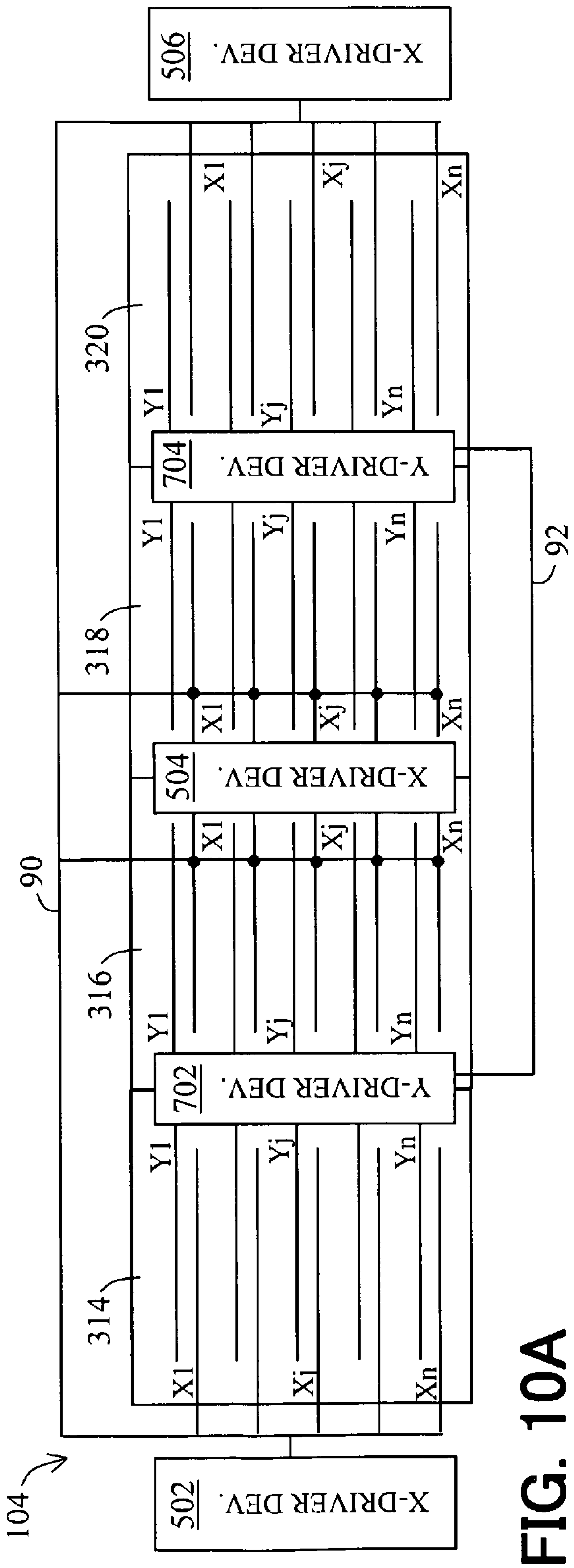

FIG. 10A

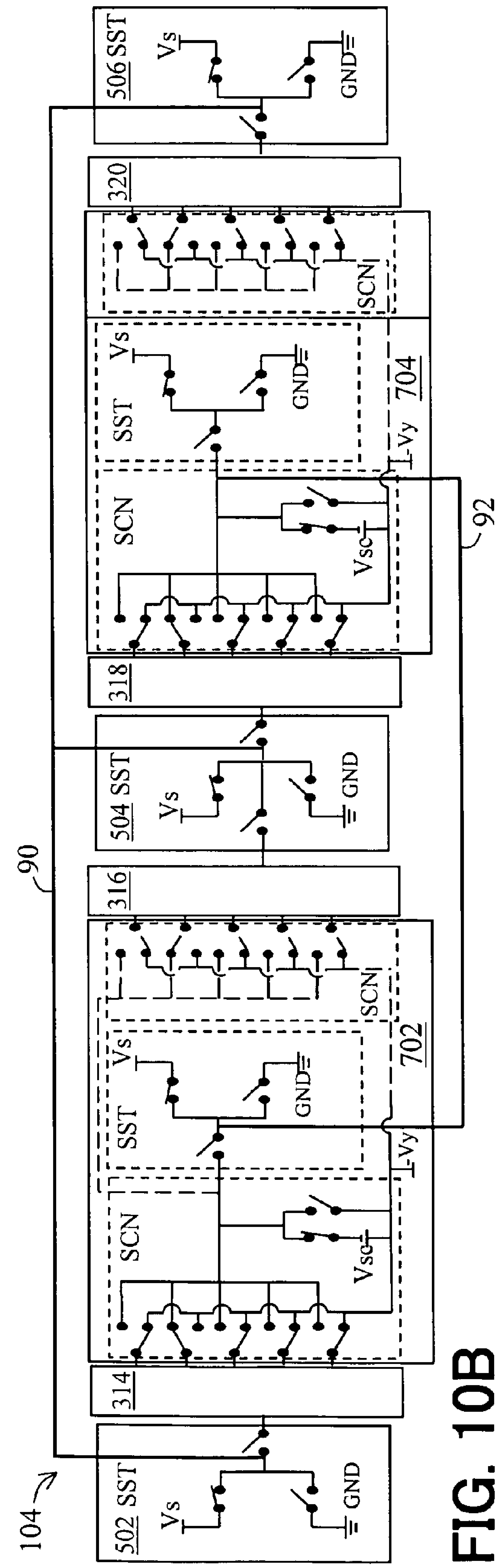

FIG. 10B

DISPLAY DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation application of international application PCT/JP2006/305370, filed Mar. 17, 2006.

FIELD OF THE INVENTION

The present invention relates generally to a large-sized display device and, more particularly, to electrical connections of display electrode driver circuits for a large-sized display device including arrays of plasma tubes each having a phosphor layer therein.

BACKGROUND OF THE INVENTION

In a plasma display panel (PDP), plasma discharge is generated in closed discharge spaces of a large number of small cells arranged in length and width directions of the panel, and phosphor materials are excited by ultraviolet light of 147 nm emitted from the discharged plasma, to thereby emit light. The cell spaces are formed between two planar glass plates disposed one on the other. On the other hand, in a plasma tube array (PTA), a phosphor layer is formed within a thin elongated glass tube or a supporting member having a phosphor layer formed thereon is inserted into the thin elongated glass tube, so that a large number of cell spaces are formed in the elongated glass tube. A large-sized display screen of 6 m×3 m, for example, can be provided by arranging a number of such plasma tubes side by side. In an ordinary plasma tube array, X-electrode sustain voltage pulses are applied to X-electrodes by an X-electrode driver device, and Y-electrode sustain voltage pulses are applied by a Y-electrode sustain voltage pulse circuit in a Y-electrode driver circuit through a scan driver circuit in the Y-electrode driver circuit.

Japanese Patent Application Publication No. 2000-47636-A describes an AC plasma display device with improved unevenness of its brightness. In the AC plasma display device, pairs of a sustain electrode and a scan electrode are divided into a first block and a second block. The first block of sustain electrodes and scan electrodes are driven by a first sustain electrode driver and a first scan electrode driver, respectively. The second block of sustain electrodes and scan electrodes are driven by a second sustain electrode driver and a second scan electrode driver, respectively. An output line of the first sustain electrode driver and an output line of the second sustain electrode driver are connected by a short-circuit line. An output line of a scan/sustain pulse generator section which forms the first scan electrode driver, and an output line of a scanning/maintaining pulse generator section which forms the second scan electrode driver are connected by a short-circuit line. Japanese Patent Application Publication No. 2004-178854-A describes a light-emitting tube array display device. The light-emitting tube array display device includes an array of light-emitting tubes forming a display screen, supports which support the array of light-emitting tubes on the display surface side and the back surface side and have a plurality of stripe electrodes for applying voltage to the light-emitting tubes formed on the sides facing the light-emitting tube array, a terminal electrode lead-out part provided on the support outside the display area of the display screen, a relay electrode lead-out part provided on the support inside the display area of the display screen, a first driver for applying voltage to the terminal electrode lead-out part, and a second driver for applying voltage to the relay electrode lead-out part. According to this arrangement, a display device with a large size screen has an electrode structure for preventing voltage drop to thereby improve unevenness of brightness of the display device.

In one PDP, the luminosity is typically controlled in the aggregate by luminosity control in accordance with the entire load rate. When the display load ratio is higher, i.e. when the luminosity of the entire screen is higher, the luminosity of the display screen as a whole is controlled to be relatively lower. On the other hand, when the display load ratio is lower, i.e. when the luminosity of the display screen as a whole is lower, the luminosity of the screen as a whole is made to be relatively higher. Thus, when one picture is displayed with a plurality of display units, there may be variations in luminosity among the units. It is known to control a plurality of driver circuits for a PDP composed of a plurality of display units, by means of software implemented on a control circuit, to reduce variations in luminosity among the display units.

DISCLOSURE OF THE INVENTION

In a large-sized display device composed of adjacently disposed plural units of plasma tube arrays with respective driver circuits, components of resistance, inductance and/or capacitance of display electrodes may affect the driving by the driver circuits. In particular, when a driving voltage is applied to a display device including electrodes longer than a specific length, the impedance of the electrodes may hamper application of a sufficient voltage for driving the display device to the electrodes over their entire length. Thus, there is a limit to the length of display electrodes driven by a driver circuit connected to ends of the electrodes. When the display electrodes of the plural units are driven by one driver circuit, the total length of the display electrodes is too long for potential distribution along the length of the display electrodes to be uniform, and, particularly, the voltage applied in the end portion of the display screen opposite to the end where the driver circuit is connected cannot be sufficiently high. This may cause luminosity unevenness, or may cause picture regions, e.g. white picture regions, of the plural units, which should have the same luminosity, to have different luminosities due to the luminosity control made for different load ratios of the units by the respective driver circuits. Difference in luminosity between picture regions of the plural units, which should have the same luminosity, cannot be sufficiently decreased by controlling the respective driver circuits for the plural units by means of software.

The inventors have recognized that, in a large-sized display device including plasma tube array units disposed adjacent to each other having respective drive circuits therefor, unevenness in luminosity among the units can be significantly reduced by advantageously designing the disposition and connections of the plural display driver circuits for the plural plasma tube array units.

An object of the invention is to reduce unevenness in luminosity in a large-sized display device including plural display units.

Another object of the invention is to reduce unevenness in luminosity between display units of a large-sized display device including such display units.

A further object of the invention is to reduce unevenness in luminosity in each of display units of a large-sized display device including such display units.

SUMMARY OF THE INVENTION

In accordance with an aspect of the present invention, a display device includes a plurality of units, each unit including a plurality of gas discharge tubes disposed adjacent to each other. Each of the gas discharge tube has a phosphor layer formed therein and is filled with discharge gas. Each of the gas discharge tubes further has a plurality of light emitting points along a longitudinal direction thereof. Each of the units further includes a plurality of pairs of display electrodes disposed on display surface sides of the plurality of gas discharge tubes, and a plurality of signal electrodes disposed on rear surfaces of the plurality of gas discharge tubes. The display device further includes at least one scan driver circuit which applies a scan voltage to corresponding display electrodes of the respective pairs of display electrodes of the plurality of units during a first period of time, and applies a sustain voltage pulse to the corresponding display electrodes during a second period of time. The one scan driver circuit applies the scan voltage to one display electrode of each of the pairs of display electrodes of adjacent two of the plurality of units, and applies the sustain voltage pulse to the one display electrode during the second period of time. The display device further includes at least two sustain voltage circuits which apply a potential for a sustain voltage pulse to the other display electrodes of the respective pairs of display electrodes of the plurality of units during the second period of time. At least one of the at least two sustain voltage circuits applies the potential for a sustain voltage pulse to the other display electrode of each of the pairs of display electrodes of at least one of outermost ones of the plurality of units.

The at least two sustain voltage circuits and the at least one scan drive circuit may be alternately disposed in the vicinity of corresponding ones from a group comprised of one of two outermost sides of the plurality of units, borders between adjacent ones of the plurality of units, and the other of the two outermost sides. The number of the plurality of units may be even, and the number of the at least one scan drive circuit may be smaller than the number of the at least two sustain voltage circuits.

The other corresponding display electrodes of the pairs of display electrodes of ones of the plurality of units may be electrically connected together via a conductor.

According to the invention, unevenness in luminosity in a large-sized display device including display units can be reduced, and unevenness in luminosity between display units and in each display unit of a large-sized display device including such units can be reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an example of a schematic structure of part of an array of plasma tubes or gas discharge tubes of a typical color display device;

FIG. **2**A illustrates the front support with a plurality of pairs of transparent display electrodes formed thereon, and FIG. **2**B illustrates the rear support with a plurality of signal electrodes formed thereon;

FIG. **3** illustrates the cross-section of the structure of the array of plasma tubes of the display device in a plane perpendicular to the longitudinal direction;

FIG. **4** illustrates electrical connections of an X-electrode driver unit, a Y-electrode driver unit and address electrode driver circuits, of the typical display device;

FIG. **5** illustrates a schematic driving sequence of output driving voltage waveforms of the X-electrode driver circuit, the Y-electrode driver circuit and the address driver circuit, in the typical display device;

FIG. **6** illustrates schematic typical configurations of an X-electrode sustain voltage pulse circuit of an X-electrode driver device and a Y-electrode sustain voltage pulse circuit and a scan pulse circuit of a Y-electrode driver device, which are coupled to a single unit of a plasma tube array;

FIG. **7**A illustrates possible disposition and connections of two X-electrode driver devices and two Y-electrode driver devices which are connected to three plasma tube array units;

FIG. **7**B illustrates potential distribution in the horizontal direction and brightness or luminosity distribution in the horizontal direction, on the X- and Y-display electrodes, when a uniform luminosity picture is displayed in the three plasma tube array units, according to the possible disposition and connections of the two X-electrode driver devices and the two Y-electrode driver devices;

FIG. **8**A schematically illustrates disposition and connections of two X-electrode driver devices and one Y-electrode driver device which are connected to two plasma tube array units of a display device, in accordance with an embodiment of the invention;

FIG. **8**B illustrates a structure in a cross-section in a plane perpendicular to the length of the tubes of the plasma tube array units, for illustrating how to connect the two X-electrode driver devices and the one Y-electrode driver device to the X-electrodes and the Y-electrodes of the plasma tube array units;

FIG. **8**C illustrates sustain pulse potential distribution in the horizontal direction and brightness or luminosity distribution in the horizontal direction, on the X- and Y-display electrodes, when a uniform luminosity picture is displayed on the two plasma tube array units, in accordance with the disposition and connections of the two X-electrode driver devices and the one Y-electrode driver device of FIG. **8**A;

FIG. **9**A schematically illustrates disposition and connections of the two X-electrode driver devices and the two Y-electrode driver devices which are connected to the three plasma tube array units of a display device, in accordance with another embodiment of the invention, and FIG. **9**B illustrates connections between the X-electrode driver devices and between Y-electrode driver devices; and

FIG. **10**A schematically illustrates disposition and connections of the three X-electrode driver devices and the two Y-electrode driver devices connected to the four plasma tube array units of a display device, in accordance with a further embodiment of the invention, and FIG. **10**B illustrates connections between the X-electrode devices and between the Y-electrode driver devices.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The embodiments of the invention will be described with reference to the accompanying drawings. Throughout the drawings, similar symbols and numerals indicate similar items and functions.

FIG. **1** illustrates an example of a schematic structure of part of an array of plasma tubes or gas discharge tubes **11**R, **11**G and **11**B of a typical color display device **10**. In FIG. **1**, the display device **10** includes an array of thin, elongated transparent color plasma tubes **11**R, **11**G, **11**B, . . . , disposed in parallel with each other, a front support plate **31** composed of a transparent front support sheet or thin plate, a rear support plate **32** composed of a transparent or opaque rear support sheet or thin plate, a plurality of pairs of display or main electrodes **2**, and a plurality of signal or address electrodes **3**. In FIG. **1**, a letter X represents a sustain or X electrode of the display electrodes **2**, and a letter Y represents a scan or Y electrode of the display electrodes **2**. Letters R, G and B represent red, green and blue, which are colors of light emitted by the phosphors. The front and rear support plates **31** and **32** are made of, for example, flexible or elastic PET or glass films or sheets.

A thin elongated tube **20** for the thin elongated plasma tubes **11**R, **11**G and **11**B is formed of a transparent, insulating material, e.g. borosilicate glass, Pyrex®, soda-lime glass, silica glass, or Zerodur. Typically, the tube **20** has cross-section dimensions of a tube diameter of 2 mm or smaller, for example a 0.55 mm high and 1 mm wide cross section, and a tube length of 300 mm or larger, and a tube wall thickness of about 0.1 mm.

Phosphor support members having respective red, green and blue (R, G, B) phosphor layers **4** formed or deposited thereon are inserted into the interior rear spaces of the plasma tubes **11**R, **11**G and **11**B, respectively. Discharge gas is introduced into the interior space of each plasma tube, and the plasma tube is sealed at its opposite ends. An electron emissive film **5** of MgO is formed on the inner surface of the plasma tube **11**R, **11**G, **11**B. The phosphor layers R, G and B typically have a thickness within a range of from about 10 μm to about 30 μm.

Similarly to the gas discharge tubes **11**R, **11**G and, **11**B, the support member is formed of a insulating material, e.g. borosilicate glass, Pyrex®, silica glass, soda-lime glass, or lead glass, and has the phosphor layer **4** formed thereon. The support member can be disposed within the glass tube by applying a paste of phosphor over the support member outside the glass tube and then baking the phosphor paste to form the phosphor layer **4** on the support member, before inserting the support member into the glass tube. As the phosphor paste, a desired one of various phosphor pastes known in this technical field may be employed.

The electron emissive film **5** emits charged particles, when it is bombarded with the discharge gas. When a voltage is applied between the pair of display electrodes **2**, the discharge gas contained in the tube is excited. The phosphor layer **4** emits visible light by converting thereinto vacuum ultraviolet radiation generated in the de-excitation process of the excited discharge gas.

FIG. **2**A illustrates the front support **31** with the plurality of pairs of transparent display electrodes **2** formed thereon. FIG. **2**B illustrates the rear support **32** with the plurality of signal electrodes **3** formed thereon.

The signal electrodes **3** are formed on the front-side surface, or inner surface, of the rear support plate **32**, and extend along the longitudinal direction of the plasma tubes **11**R, **11**G and **11**B. The pitch, between adjacent ones of the signal electrodes **3**, is substantially equal to the width of each of the plasma tubes **11**R, **11**G and **11**B, which may be, for example, 1 mm. The pairs of display electrodes **2** are formed on the rear-side surface, or inner surface, of the front support plate **31** in a well-known manner, and are disposed so as to extend perpendicularly to the signal electrodes **3**. The width of the display electrode **2** may be, for example, 0.75 mm, and the distance between the edges of the display electrodes **2** in each pair may be, for example, 0.4 mm. A distance providing a non-discharging region, or non-discharging gap, is secured between one display electrode pair **2** and the adjacent display electrode pairs **2**, and the distance may be, for example, 1.1 mm.

The signal electrodes **3** and the pairs of display electrodes **2** are brought into intimately contact respectively with the lower and upper peripheral surface portions of the plasma tubes **11**R, **11**G and **11**B, when the display device **10** is assembled. In order to provide better contact, an electrically conductive adhesive may be placed between the display electrodes and the plasma tube surface portions.

In plan view of the display device **10** seen from the front side, the intersections of the signal electrodes **3** and the pairs of display electrodes **2** provide unit light-emitting regions. Display is provided by using either one electrode of each pair of display electrodes **2** as a scan electrode Y, generating a selection discharge at the intersection of the scan electrode Y with the signal electrode **3** to thereby select a light-emitting region, and generating a display discharge between the pair of display electrodes **2** using the wall charge formed by the selection discharge on the region of the inner tube surface at the selected region, which, in turn, causes the associated phosphor layer to emit light. The selection discharge is an opposed discharge generated within each plasma tube **11**R, **11**G, **11**B between the vertically opposite scan electrode Y and signal electrode **3**. The display discharge is a surface discharge generated within each plasma tube **11**R, **11**G and **11**B between the two display electrodes of each pair of display electrodes disposed in parallel in a plane.

The pair of display electrodes **2** and the signal electrode **3** can generate discharges in the discharge gas within the tube by applying voltages between them. The electrode structure of the plasma tubes **11**R, **11**G and **11**B illustrated in FIG. **1** is such that the three electrodes are disposed in one light-emitting region, and that the discharge between the pair of display electrodes **2** generates a discharge for display. However, the electrode structure is not limited to such a structure. A display discharge may be generated between the display electrode **2** and the signal electrode **3**. In other words, an electrode structure of a type employing a single display electrode may be employed instead of each pair of display electrodes **2**, in which the single display electrode **2** is used as a scan electrode so that a selection discharge and a display discharge (opposed discharge) are generated between the single display electrode **2** and the signal electrode **3**.

FIG. **3** illustrates the cross-section of the structure of the array of plasma tubes **11** of the display device **10** in a plane perpendicular to the longitudinal direction. In the display device **10**, phosphor layers **4**R, **4**G and **4**B are formed on the inner surface portions of the support members **6**R, **6**G and **6**B in the rear-half spaces of the plasma tubes **11**R, **11**G and **11**B, respectively. The plasma tubes are thin tubes having a tube thickness of 0.1 mm, a width in the cross-section of 1.0 mm, a height in the cross-section of 0.55 mm, and a length of from 1 m to 3 m. For example, the red-emitting phosphor **4**R may be formed of an yttria based material ($(Y.Ga)BO_3$:Eu), the green-emitting phosphor **4**G may be formed of a zinc silicate based material (Zn_2SiO_4:Mn), and the blue-emitting phosphor **4**B may be formed of a BAM based material ($BaMgAl_{10}O_{17}$:Eu).

In FIG. **3**, the rear support plate **32** is bonded or fixed to bottom surfaces of the red-emitting plasma tubes **11**R, **11**G and **11**B. The signal electrodes **3**R, **3**G and **3**B are disposed on the bottom surfaces of the plasma tubes **11**R, **11**G and **11**B and on an upper surface of the rear support plate **32**.

FIG. **4** illustrates electrical connections of an X-electrode driver unit **500**, a Y-electrode driver unit **700** and address electrode driver circuits **46**, of the typical display device **10**. In the display device **10**, the plasma tube array **11** has n pairs of display electrodes **2**, (X**1**,Y**1**), . . . , ((Xj, Yj), . . . , (Xn, Yn). Ones of the display electrodes **2** of the pairs of display electrodes **2** are connected from a right end portion **53**, divided into plural sections, of the front support plate **31** to a sustain voltage pulse circuit **50** for X-electrodes in the X-electrode driver unit **500** through long flexible cables **52**. In addition, the other ones of the display electrodes **2** of the pairs of display electrodes **2** are connected from a left end portion **71**, divided into plural sections, of the front support plate **31** to scan pulse circuits **70** in the Y-electrode driver unit **700**. A sustain voltage pulse circuit **60** for the Y-electrodes of the Y-electrode driver unit **800** is connected to the scan pulse circuits **70** through flexible cables. A plurality, m, of signal electrodes **3**, A**1**, . . . , Ai, . . . , Am, are connected to address driver circuits **46** from the lower end divided into plural sections. The X-electrode driver unit **500** includes also a reset circuit **51**. The Y-electrode driver unit **700** includes also a reset circuit **61**. A driver control circuit **42** is connected to the X-electrode driver circuit **500**, the Y-electrode driver circuit **700** and the address driver circuit **46**.

Now, one exemplary method for driving an AC gas discharge display device of the plasma tube array type is described. One picture typically has one frame period of approximately 16.7 ms. One frame consists of two fields in the interlaced scanning scheme, and one frame consists of one field in the progressive scanning scheme. For displaying a moving picture in a conventional television system, thirty frames per second must be displayed. In displaying on the display device **10** of this type of AC gas discharge display device, for reproducing colors by the binary control of light emission, one field F is typically divided into or replaced with a set of q subfields SF's. Often, the number of times of discharging for display for each subfield SF is set by weighting these subfields SF's with respective weighting factors of $2^0, 2^1, 2^2, \ldots, 2^{q-1}$ in this order. N $(=1+2^1+2^2+\ldots+2^{q-1})$ steps of brightness can be provided for each color of R, G and B in one field by associating light emission or non-emission with each of the subfields in combination. In accordance with such a field structure, a field period Tf, which represents a cycle of transferring field data, is divided into q subfield periods Tsf's, and the subfield periods Tsf's are associated with respective subfields SF's of data. Furthermore, a subfield period Tsf is divided into a reset period TR for initialization, an address period TA for addressing, and a display or sustain period TS for emitting light. Typically, the lengths of the reset period TR and the address period TA are constant independently of the weighting factors for the brightness, while the number of pulses in the display period TS becomes larger as the weighting factor becomes larger, and the length of the display period TS becomes longer as the weighting factor becomes larger. In this case, the length of the subfield period Tsf becomes longer, as the weighting factor of the corresponding subfield SF becomes larger.

FIG. **5** illustrates a schematic driving sequence of output driving voltage waveforms of the X-electrode driver circuit **500**, the Y-electrode driver circuit **700** and the address driver circuit **42**, in the typical display device **10**. The waveform illustrated is an example, and the amplitudes, polarities and timings of the waveforms may be varied differently.

The q subfields SF's have the same order of the reset period TR, the address period TA and the sustain period TS in the driving sequence, and this sequence is repeated for each subfield SF. During the reset period TR of each subfield SF, a negative polarity pulse Prx**1** and a positive polarity pulse Prx**2** are applied in this order to all of the display electrodes X's, and a positive polarity pulse Pry**1** and a negative polarity pulse Pry**2** are applied in this order to all of the display electrodes Y's. The pulses Prx**1**, Pry**1** and Pry**2** have ramping waveforms having the amplitudes which gradually increase at the rates of variation that produce micro-discharge. The first pulses Prx**1** and Pry**1** are applied to produce, in all of the cells, appropriate wall voltages having the same polarity, regardless of whether the cells have been illuminated or unilluminated during the previous subfield. Subsequently, the second pulses Prx**2** and Pry**2** are applied to the discharge cells on which an appropriate amount of wall charge is present, which adjusts the wall charge to decrease to a level (blanking state) at which sustain pulses cannot cause re-discharging. The driving voltage applied to the cell is a combined voltage which represents difference between the amplitudes of the pulses applied to the respective display electrodes X and Y.

During the address period TA, wall charges required for sustaining illumination are formed only on the cells to be illuminated. While all of the display electrodes X's and of the display electrodes Y's are biased at the respective predetermined potentials, a negative scan pulse voltage −Vy is applied to a row of a display electrode Y corresponding to a selected row for each row selection interval (a scan interval for one row of the cells). Simultaneously with this row selection, an address pulse voltage Va is applied only to address electrodes A's which correspond to the selected cells to produce address discharges. Thus, the potentials of the address electrodes A**1** to Am are binary-controlled in accordance with the subfield data Dsf for m columns in the selected row j. This causes address discharges to occur in the discharge tubes of the selected cells between the display electrode Y's and the address electrode A's, and the display data written by the address discharges is stored in the form of wall charges on the cell inner walls of the discharge tubes. A sustain pulse applied subsequently causes surface discharges between the display electrodes X's and Y's.

During the sustain period TS, a first sustain pulse Ps is applied so that a polarity of the first sustain pulse Ps (i.e., the positive polarity in the illustrated example) is added to the wall charge produced by the previous address discharge to cause a sustain discharge. Then, the sustain pulse Ps is applied alternately to the display electrodes X's and the display electrodes Y's. The amplitude of the sustain pulse Ps corresponds to the sustain voltage Vs. The application of the sustain pulse Ps produces surface discharge in the discharge cells which have a predetermined amount of residual wall charge. The number of applied sustain pulses Ps's corresponds to the weighting factor of the subfield SF as described above. In order to prevent undesired opposite discharge between the opposite electrodes during the entire sustain period TS, the addressing electrodes A's are biased at a voltage Vas having the same polarity as the sustain pulse Ps.

FIG. **6** illustrates schematic typical configurations of an X-electrode sustain voltage pulse circuit **50** of an X-electrode driver device **500**, and of a Y-electrode sustain voltage pulse circuit (SST) **60** and a scan pulse circuit (SCN) **70** of a Y-electrode driver device **700**. These pulse circuits **50**, **60** and **70** are coupled to a single unit of a plasma tube array **310**.

The sustain voltage pulse circuit (SST) **50** includes a bias voltage source Vs to be coupled to X-electrodes X**1**-Xn via a switch, and ground potential GND to be coupled to X-electrodes X**1**-Xn via a switch.

The sustain voltage pulse circuit (SST) **60** includes a high pulse voltage source Vs coupled to the scan pulse circuit (SCN) **70** via a switch, and ground potential GND coupled to the scan pulse circuit **70** via a switch. The scan pulse circuit (SCN) **70** couples the pulse voltage source Vs and the ground potential GND to Y-electrodes Y**1**-Yn. The scan pulse circuit **70** further includes a bias voltage source Vsc to be coupled to the Y-electrodes Y**1**-Yn via a switch, and a scan pulse source −Vy to be coupled to the Y-electrodes Y**1**-Yn via a switch.

FIG. **7**A illustrates possible disposition and connections of two X-electrode driver devices **500** and **501** and two Y-electrode driver devices **700** and **701**, which are connected to three plasma tube array units **311**, **312** and **313**. FIG. **7**B illustrates potential distribution in the horizontal direction and brightness or luminosity distribution in the horizontal direction, on the X- and Y-display electrodes, when a picture of uniform luminosity, e.g. white, is displayed, in the three plasma tube array units **311**, **312** and **313**, in accordance with the possible disposition and connections of the two X-electrode driver devices **500** and **501** and the two Y-electrode driver devices **700** and **701**.

Referring to FIG. **7**A, one X-electrode driver device **500** is disposed on the left side of the left unit **311** and connected to the X-electrodes of the unit **311**. The other X-electrode driver device **501** is disposed on the right side of the unit **313** and connected to the X-electrodes of the unit **313**. The X-electrodes of the units **311** and **313** are connected to the X-electrodes of the center unit **312**. One Y-electrode driver device **700** is disposed on the right side of the left unit **311**, which is the left side of the center unit **312**, and connected to the Y-electrodes of the units **311** and **312**. The other Y-electrode driver device **701** is disposed on the left side of the right unit **313**, which is the right side of the center unit **312**, and connected to the Y-electrodes of the units **312** and **313**.

Referring to FIG. **7**B, the brightness, or luminosity, of the screen is generally proportional to the sum of the sustain pulse potential on the X-electrode and the sustain pulse potential of the Y-electrode. The luminosity in the horizontal direction in the left unit **311** and right unit **313** is substantially uniform. On the other hand, the luminosity at the horizontal center of the center unit **312** is very low. This is so because the centers of the X-electrodes of the center unit **312** are remote from the X-electrode driver devices **500** and **501**. When the entire area of the display screen of the unit **311** exhibits a high luminosity, e.g. white, and a half of the area of the display screen of the unit **313** exhibits the same high luminosity, e.g. white, with the remaining half exhibiting a lower luminosity, e.g. black, the luminosity of white of the unit **311** is decreased and the luminosity of white of the unit **313** is increased by the luminosity control provided by the X-electrode driver devices **500** and **501**, so that there is difference in luminosity between the units **311** and **313**.

FIG. **8**A schematically illustrates disposition and connections of two X-electrode driver devices **502** and **504** and one Y-electrode driver device **702**, which devices are connected to two plasma tube array units **314** and **316** of a display device **100**, in accordance with an embodiment of the invention. FIG. **8**B illustrates a structure in a cross-section in a plane perpendicular to the length of the tubes of the plasma tube array units **314** and **316**, for illustrating how to connect the two X-electrode driver devices **502** and **504** and the one Y-electrode driver device **702** to the X-electrodes and the Y-electrodes of the plasma tube array units **314** and **316**. FIG. **8**C illustrates sustain pulse potential distribution in the horizontal direction and brightness or luminosity distribution in the horizontal direction, on the X- and Y-display electrodes, when a picture of uniform luminosity, e.g. white, is displayed, on the two plasma tube array units **314** and **316**, in accordance with the disposition and connections of the two X-electrode driver devices **502** and **504** and the one Y-electrode driver device **702** of FIG. **8**A.

In FIGS. **8**A and **8**B, the left-side unit **314** and the right-side unit **316** are adjacently disposed side by side in the horizontal direction. The length of each of the units **314** and **316** measured in the horizontal direction may be one meter (1 m), for example. A sustain voltage output terminal of one X-electrode driver device **502** is disposed on the left side of the unit **314** and is connected to the X-electrodes of the unit **314**. A sustain voltage output terminal of the other X-electrode driver device **504** is disposed on the right side of the unit **316** and is connected to the X-electrodes of the unit **316**. Scan and sustain voltage output terminals of the Y-electrode driver device **702** are disposed on the right side of the left unit **314**, which is the left side of the unit **316**, and are connected to the Y-electrodes of the units **314** and **316**. The X-electrode driver device(s) **502** and/or **504** may be disposed either on opposite sides or on one side of the display device **100**. By disposing the Y-electrode driver device **702** between the units **314** and **316**, or, in other words, by using a smaller number of the Y-electrode driver device **702**, which has circuitry of a larger scale, than the X-electrode driver devices **502** and **504** having circuitry of a smaller scale, the scale of the entire driver circuitry of the display device **100** can be made smaller and, thus, less expensive.

Referring to FIG. **8**C, it is seen that the difference in sustain potential in the horizontal direction between the X- and Y-electrodes is from about 10 V to about 15 V at the maximum. By virtue of the disposition and connections of the display device **100** of FIGS. **8**A and **8**B, the sum of the X-electrode sustain potential and the Y-electrode sustain potential in the horizontal direction on the display screen formed by the units **314** and **316** is substantially constant, which results in substantial uniformity in brightness or luminosity over the display screen formed by the units **314** and **316**.

In FIGS. **8**A and **8**B, the left side of the unit **314** and the right side of the unit **316** are disposed adjacent to and in contact with each other. Y-electrodes led out from the right side of the unit **314** and Y-electrodes led out from the left side of the unit **316** are connected to common terminals of the Y-electrode driver device **702** disposed on the rear side of the units **314** and **316**, with each Y-electrode at the right side of the unit **314** connected to the Y-electrode of the same row at the left side of the unit **316**. This arrangement allows the luminosity control by the Y-electrode driver device **702** to control the luminosities of the two units **314** and **316** in accordance with the sum of their load ratios.

The X-electrode portions led out from the left side of the unit **314** are connected to the X-electrode driver device **502** disposed on the rear side of the unit **314**. The X-electrode portions led out from the right side of the unit **316** are connected to the X-electrode driver device **504** disposed on the rear side of the unit **316**. The sustain voltage output terminals of the X-electrode driver devices **502** and **504** are connected together by a conductor **90**, e.g. a copper wire. Alternatively, the conductor **90** may connect the X-electrodes at the left side of the unit **314** to the X-electrodes at the right side of the unit **316**. The conductor **90** may be a copper strip or elongated plate having small impedance.

In this manner, current supplied from an X-electrode power supply (i.e. the sustain voltage pulse circuit **50**) in the X-electrode driver device **502** can be made substantially equal to the current supplied from an X-electrode power supply (i.e. the sustain voltage pulse circuit **50**) in the X-electrode driver device **504**. This compensates for the difference between the units **314** and **316**. In addition, the luminosity control by the two X-electrode driver devices **502** and **504** with the same circuit configuration allows proper control of the respective unit luminosities in accordance with the sum of the load ratios on the two units **314** and **316**, to thereby sufficiently reduce the luminosity difference or luminosity unevenness present between regions of plural units where the luminosity should be equal.

FIG. **9**A schematically illustrates disposition and connections of the two X-electrode driver devices **502** and **504** and the two Y-electrode driver devices **702** and **704**, which are connected to the three plasma tube array units **314**, **316** and **318** of a display device **102**, in accordance with another embodiment of the invention. FIG. **9**B illustrates the connections between the X-electrode driver devices **502** and **504** and the connections between Y-electrode driver devices **702** and **704**. The connections of the X-electrode driver devices **502** and **504** to the plasma tube array units **314**, **316** and **318** is similar to the connections of the X-electrode driver devices **502** and **504** and the Y-electrode driver device **702** in FIG. **8**B. The sustain voltage output terminals of the Y-electrode driver devices **702** and **704** are connected together via a conductor **92**.

In FIG. **9**A, the units **314**, **316** and **318** are adjacently disposed side by side in the horizontal direction. One X-electrode driver device **502** is disposed on the left side of the unit **314** and is connected to the X-electrodes of the unit **314**. Another X-electrode driver device **504** is disposed on the right side of the unit **316**, which is the left side of the unit **318**, and is connected to the X-electrodes of the units **316** and **318**. The Y-electrode driver device **702** is disposed on the right side of the left-hand side unit **314**, which is the left-hand side of the unit **316**, and is connected to the Y-electrodes of the units **314** and **316**. The Y-electrode driver device **704** is disposed on the right side of the unit **318** and is connected to the Y-electrodes of the unit **318**. In the sustain voltage pulse circuit SST of the Y-electrode driver device **702** of FIG. **9**B, switch connections indicated by broken lines in the right-hand side portion of FIG. **9**B represents mirror-symmetry of switch connections on the left-hand side portion.

With the disposition and connections of the display device **102** of FIGS. **9**A and **9**B, the sum of the X-electrode potential and the Y-electrode potential in the horizontal direction on the display screen formed by the units **314**, **316** and **318** is substantially constant, and, hence the brightness, or luminosity, over the display screen formed by the units **314**, **316** and **318** is substantially uniform.

The X-electrode driver device **504** may be adjusted or adapted so as to have current supply capacity for the X-electrode sustain voltage two times as large as that of the X-electrode driver device **502**. The X-electrodes on the left side of the unit **314** are connected to the X-electrodes on the right side of the unit **316** and the X-electrodes on the left side of the unit **318** via the conductor **90** on the rear side of the units **314**, **316** and **318**. Accordingly, current supplied by the X-electrode power supply (i.e., the sustain voltage pulse circuit **50**) of the X-electrode driver device **502** is substantially equal to one-half of the current supplied by the X-electrode power supply (i.e., the sustain voltage pulse circuit **50**) of the X-electrode driver device **504**. Further, the luminosity control by the X-electrode driver devices **502** and **504** allows proper control of the respective unit luminosities in accordance with the sum of the load ratios of the three units **314**, **316** and **318**.

The Y-electrodes on the right side of the unit **318** are connected to the X-electrodes on the right side of the unit **314** and to the X-electrodes on the left side of the unit **316**, through a conductor **92** on the rear side of the units **314**, **316** and **318**. The conductor **92** may be a thin copper strip or elongated plate exhibiting low impedance. Further, the luminosity control by the Y-electrode driver devices **702** and **704** allows proper control of the respective unit luminosities in accordance with the sum of the load ratios of the three units **314**, **316** and **318**. The power supply capacity for all of the X-electrode driver devices **502** and **504** and all of the Y-electrode driver devices **702** and **704** may be required to be sufficient to supply power to all the units **314**, **316** and **318** for proper display.

FIG. **10**A schematically illustrates disposition and connections of the three X-electrode driver devices **502**, **504** and **506** and the two Y-electrode driver devices **702** and **704** connected to the four plasma tube array units **314**, **316**, **318** and **320** of a display device **104**, in accordance with a further embodiment of the invention. FIG. **10**B illustrates the connections between the X-electrode devices **502**, **504** and **506**, and the connections between the Y-electrode driver devices **702** and **704**. The manner of connecting the X-electrode driver devices **502**, **504** and **506** to the X-electrodes of the plasma tube array units **314**, **316**, **318** and **320** is similar to the connections of the X-electrode driver devices **502** and **504** of FIGS. **9**A and **9**B. The manner of connecting the Y-electrode driver devices **702** and **704** to the Y-electrodes of the plasma tube array units **314**, **316**, **318** and **320** is similar to the connections of the Y-electrode driver devices **702** and **704** of FIGS. **9**A and **9**B.

In FIG. **10**A, the units **314**, **316**, **318** and **320** are adjacently disposed horizontally side by side. The X-electrode driver device **502** is disposed on the left side of the unit **314** and is connected to the X-electrodes of the unit **314**. The X-electrode driver device **504** is disposed on the right side of the unit **316**, which is the left side of the unit **318**, and is connected to the X-electrodes of the units **316** and **318**. The X-electrode driver device **506** is disposed on the right side of the unit **320** and is connected to the X-electrodes of the unit **320**. The Y-electrode driver device **702** is disposed on the right side of the left unit **314**, which is the left side of the unit **316**, and is connected to the Y-electrodes of the units **314** and **316**. The Y-electrode driver device **704** is disposed on the right side of the unit **318**, which is the left side of the unit **320**, and is connected to the Y-electrodes of the units **318** and **320**. Switch connections indicated by broken lines in the right-hand side portion of each of the sustain voltage pulse circuits SST of the Y-electrode driver devices **702** and **704** of FIG. **10**B represents mirror-symmetry of switch connections on the left-hand side portion. The entire driver circuitry of display device **104** can be smaller in scale, to thereby reduce the cost of the display device **104**, by virtue of using a smaller number of the Y-electrode driver devices **702** and **704**, which have large scale circuits, than the number of the X-electrode driver devices **502**, **504** and **506**, which have small scale circuits.

With the disposition and connections of the display device **104** of FIGS. **10**A and **10**B, the sum of the X-electrode potential and the Y-electrode potential in the horizontal direction on the display screen formed by the units **314**, **316**, **318** and **320** is substantially constant, and hence the brightness, or luminosity, over the display screen formed by the units **314**, **316**, **318** and **320** is substantially uniform.

The sustain voltage output terminals of the sustain voltage pulse circuits SST of the Y-electrode driver devices **702** and **704** are connected together by the conductor **92**. This connection allows the current supplied by the Y-electrode power supply (the sustain voltage pulse circuit SST) of the Y-electrode driver device **702** to be substantially equal to the current supplied by the Y-electrode power supply (the sustain voltage pulse circuit SST) of the Y-electrode driver device **704**.

The above-described embodiments are only typical examples, and their combination, modifications and variations are apparent to those skilled in the art. It should be noted that those skilled in the art can make various modifications to the above-described embodiments without departing from the principle of the invention and the accompanying claims.

What is claimed is:

1. A display device comprising:

a plurality of plasma tube array units disposed adjacent to each other in a longitudinal direction of display electrodes thereof, each plasma tube array unit comprising a plurality of plasma tubes disposed adjacent to each other, each of the plasma tubes of a plasma tube array unit having a phosphor layer formed therein and being filled with discharge gas, each of the plasma tube array units further comprising a plurality of pairs of the display electrodes disposed on display surface sides of the plurality of plasma tubes of the plasma tube array unit and extending in a direction crossing a longitudinal direction of the plasma tubes of the plasma tube array unit, and a plurality of signal electrodes, each disposed on rear surfaces of the plurality of plasma tubes of the plasma tube array unit along the longitudinal direction of the respective plasma tubes of the plasma tube array unit;

at least one scan driver circuit which applies a scan voltage and a sustain voltage to certain corresponding display electrodes of the respective pairs of display electrodes of two adjacent plasma tube array units at a position between the two adjacent plasma tube array units; and

at least two sustain driver circuits which apply sustain voltages to other than the certain display electrodes of the respective pairs of display electrodes of the plurality of plasma tube array units, wherein the two sustain driver circuits apply the sustain voltages to the other than the certain display electrodes of the pairs of display electrodes of the two adjacent plasma tube array units on two respective outer sides of the two adjacent plasma tube array units.

2. The display device according to claim **1**, wherein the at least two sustain driver circuits and the at least one scan drive circuit are alternately disposed in the vicinity of corresponding ones from a group comprised of one of two outermost sides of the plurality of plasma tube array units, borders between adjacent ones of the plurality of plasma tube array units, and the other of the two outermost sides.

3. The display device according to claim **2**, wherein the number of the plurality of plasma tube array units is even, and the number of the at least one scan drive circuit is smaller than the number of the at least two sustain driver circuits.

4. The display device according to claim **3**, wherein a sum of the sustain voltages on one and the other display electrodes of each of the pairs of display electrodes of each of the plurality of plasma tube array units at a given location along the length of that pair of display electrodes is substantially equal to a sum of the sustain voltages on one and the other display electrodes of each of the pairs of display electrodes of each of the plurality of plasma tube array units at a different location along the length of that pair of display electrodes.

5. The display device according to claim **4**, wherein the at least two sustain driver circuits are electrically connected together via a conductor.

6. The display device according to claim **3**, wherein the at least two sustain driver circuits are electrically connected together via a conductor.

7. The display device according to claim **2**, wherein a sum of the sustain voltages on one and the other display electrodes of each of the pairs of display electrodes of each of the plurality of plasma tube array units at a given location along the length of that pair of display electrodes is substantially equal to a sum of the sustain voltages on one and the other display electrodes of each of the pairs of display electrodes of each of the plurality of plasma tube array units at a different location along the length of that pair of display electrodes.

8. The display device according to claim **7**, wherein the at least two sustain driver circuits are electrically connected together via a conductor.

9. The display device according to claim **2**, wherein the at least two sustain driver circuits are electrically connected together via a conductor.

10. The display device according to claim **1**, wherein the number of the plurality of plasma tube array units is even, and the number of the at least one scan drive circuit is smaller than the number of the at least two sustain driver circuits.

11. The display device according to claim **10**, wherein a sum of the sustain voltages on one and the other display electrodes of each of the pairs of display electrodes of each of the plurality of plasma tube array units at a given location along the length of that pair of display electrodes is substantially equal to a sum of the sustain voltages on one and the other display electrodes of each of the pairs of display electrodes of each of the plurality of plasma tube array units at a different location along the length of that pair of display electrodes.

12. The display device according to claim **11**, wherein the at least two sustain driver circuits are electrically connected together via a conductor.

13. The display device according to claim **10**, wherein the at least two sustain driver circuits are electrically connected together via a conductor.

14. The display device according to claim **1**, wherein a sum of the sustain voltages on one and the other display electrodes of each of the pairs of display electrodes of each of the plurality of plasma tube array units at a given location along the length of that pair of display electrodes is substantially equal to a sum of the sustain voltages on one and the other display electrodes of each of the pairs of display electrodes of each of the plurality of plasma tube array units at a different location along the length of that pair of display electrodes.

15. The display device according to claim **14**, wherein the at least two sustain driver circuits are electrically connected together via a conductor.

16. The display device according to claim **1**, wherein the at least two sustain driver circuits are electrically connected together via a conductor.

17. A display device of a plasma tube array type comprising:

two or more plasma tube array units, each plasma tube array unit comprising pairs of scan and sustain electrodes, wherein the two or more plasma tube array units are disposed adjacent to each other in a longitudinal direction of the scan and sustain electrodes,

at least one scan driver, the one scan driver coupled to the scan electrodes of the two adjacent plasma tube array units at a position between the two adjacent plasma tube array units, to apply a scan signal and/or a sustain voltage to the scan electrodes of the two adjacent plasma tube array units; and

at least two sustain drivers, the two sustain drivers coupled to the respective sustain electrodes of the two respective adjacent plasma tube array units on two respective outer sides of the two respective adjacent plasma tube array units, to apply respective sustain voltages to the sustain electrodes of the two adjacent plasma tube array units.

* * * * *